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Effects of Temperature on *Mucuna solannie* Water-Based Mud Properties

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Abstract— *Water-based mud formulated from Mucuna solannie seeds, a leguminous plant, has been proved to be efficient and cost effective. Hence, the effects of temperature on the properties of the mud formulated from Mucuna solannie have been shown to follow similar trend as other mud formulations-water or oil based. Properties at temperatures of 95ºF, 120ºF and 180ºF gave decreased values of Plastic Viscosity, Yield Point, Low Shear Rate Yield Point and Apparent Viscosity with increase in temperature, while an increase in Fluid Loss was recorded with temperature increase for both unweighted and weighted muds. Mud properties at temperature up to 212ºF and above should not be found without a corresponding increase in mud pressure to prevent boiling.*

Keywords— ***Fluid Loss, Mucuna solannie, Plastic Viscosity, Temperature, Yield Point.***

I. INTRODUCTION

A drilling fluid is any fluid (gas or liquid) used in rotary drilling that is circulated from the surface down the drillstring, through the drill bit and up the annulus to the surface, and performs several functions as it completes the circuit. One critical function the drilling fluid performs is to minimize cuttings concentration around the bit and throughout all the sections in the annular space. Mud is a drilling fluid (oil or water), which is often a dirty mixture of water and clay or polymers. Drilling mud circulation brought efficiency to the rotary drilling system by floating cuttings to the surface which was not obtainable from the cable tool drilling system. Hence, the circulating system became a major component of the rig – a device for drilling, casing and cementing of oil, gas and water wells.

Physical properties of materials such as the phase (liquid, solid, gaseous and plasma), density, solubility, vapor pressure, and electrical conductivity depend on temperature. Similarly, the rate and extent of chemical reactions all depend on temperature. Hence, the effect of temperature on fluids (drilling mud) cannot be overemphasized.

II. LITERATURE REVIEW

Several researches have been carried out on the use of local materials as additives for viscosity and fluid loss control in water based drilling muds in Nigeria. These are all geared towards the local content drive of the Federal Government of Nigeria.

It has been reported that local polymers have the ability to be used as substitutes for imported samples to control viscosity [2]. In their work, cassava starch was used to formulate a water based mud where it served as a viscosifier. Though their formulation showed lower viscosity value compared with drilling fluid formulated from/with conventional materials, they stressed on the importance of proper quality control efforts of the local samples, for them to be used as substitutes for imported materials.

A mud was also formulated from local materials, which included *Detarium microcarpum*, *Brachystegia eurycoma* and *Pleurotus* [4]. The *Detarium microcarpum* was used as a viscosifier, while the Brachystegia e. and Pleurotus were used as fluid loss control agents with slight viscosifying effects. They summarized the composition of *Detarium microcarpum* as 42% of carbohydrate and 7% of oil with 72% of potassium ions for shale inhibition. He analyzed the composition of *Brachystegia eurycoma* based on previous works which includes oil, protein and carbohydrate, with potassium and iron in significant amounts. He also pointed out that *Pleurotus* contains high concentration of fiber which is the main source of the fluid loss control. Though the *Brachystegia eurycoma* afforded both fluid loss and viscosifier functions, the fluid losses recorded at ambient temperature, 120ºF, 150ºF and 180ºF were observed to be higher than the values from a conventional mud at the specified temperature values. He recorded the same trend for the unweighted mud, low solids mud and the weighted mud. Good hole cleaning results based on cuttings transport efficiency and cuttings concentration were observed in the 8 ½-in hole section. His economic evaluation showed that the extra expenditure in the use of the conventional PAC/XCD polymer mud is not worth it, since the cheaper biomaterials

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mud could be preferentially selected in terms of cost effectiveness.

It has also been proved that the locally sourced material, Irvingia gabonensis, when used in combination with pre-hydrated bentonite could produce a water based drilling fluid with understandable shear thinning characteristics [9]. In their work, starch was included in the formulation with Irvingia gabonensis, which was not used earlier [2]. That proved the notion that combinations of local materials could result in a useable mud, but the cost implication should matter since local materials differ in prices [4].

Another work reported higher yield stress for a mud formulation from Irvingia gabonensis when compared with a conventional mud [5]. The conventional mud was used as a control test, while different combinations of local materials were prepared, tested and the results compared with the conventional mud. He based his work on a temperature range of 60ºF to 120ºF. In the work, it was highlighted that the biopolymer exhibited good transport ratio, an indicator for good wellbore cleaning capability of muds. He concluded that the mud formulation would be most suitable for shallow wells because of the temperature range on which the experiments were carried out. Though the work did not show the value of the yield of Irvingia gabonensis, he suggested the need to refine the biopolymer in order to have equal measure with the conventional polymer, and its suitability in high temperature high pressure drilling.

2.1 Properties of the Drilling Mud

Two important properties are needed for mud to performs all its functions [10];

- **Viscosity**- oil and water have viscosities around 1 cP; hence a component is needed to increase their viscosities. *The viscosifiers could be clay and polymers.*
- **Density**- oil and water have densities of around 50.5 lb/ft^3 and 62.4 lb/ft^3 respectively; hence a density giver is needed to increase their densities. They include Barite ($BaSO_4$) and soluble salts (brines).

However, different mud properties may affect a particular mud function. Similarly, a change in one mud property may affect more than one mud function.

Mud properties should be recognized for their influence on all functions and the relative importance of each function [6]. Tradeoffs are required in treating and maintaining the properties needed to accomplish the required functions. A high mud viscosity might improve borehole cleaning, yet lowers hydraulic efficiency and ROP, and increase drill solids retention.

Field experience indicates that temperature affects the properties of water and oil based muds. Also, mud properties at surface conditions are greatly different from those at conditions prevailing in the hole. For example, the viscosity of a particular lignosulfonate mud decreased by a factor of two when the temperature was increased from 80ºF to 140ºF [3]. This decrease is much more than is commonly thought to occur with such a change in temperature.

It has been shown that barite does not have the tendency to perform adequately under high temperature. Also, high temperature has been shown to cause higher fluid losses in a Niger Delta formation [8].

The filtration rate of muds increases with temperature because the viscosity of the filtrate is reduced [1]. If the mud temperature would increase to 212ºF, the pressure must be increased to prevent boiling.

Mucuna is a genus of around one hundred accepted species of climbing vines and shrubs of the family fabaceae, found worldwide in the woodlands of tropical areas [7] in several countries of Asia and Africa. Mucuna plants bear pods, and the seed pods are protected by velvety hairs. Pods are produced on long, rope-like stems that hang from the forest canopy. At maturity, each pod produces several hard, marble like seeds. *Mucuna* seeds are toasted before grinding and flouring to serve as thickener in soup or sauce. The Igbo of South-East Nigeria use it as part of main dish as thickener for soup, beverages and other food items. *Mucuna solannie* consists of high protein, high carbohydrates, low lipids, high fibre, adequate minerals, and meet the requirement of essential amino acids.

Brachystegia eurycoma are grown in South East, Nigeria, of rain forest vegetation and in other African and Asian countries. Their seeds are used in making soup as thickener. An analysis indicated that the oil content was 5.87±0.30mg/100g. The seeds are rich in protein and carbohydrate. The protein content ranges from 11.82 $\pm$ 0.25mg/100g dry matter.

Pleurotus contains high concentration of fiber which could be the main source of the fluid loss control in muds.

III. METHODOLOGY

3.1 The lists of some laboratory equipment/materials are presented in TABLE 3.1.

Table.3.1: Laboratory Equipment used

• Six-speed viscometer
• Hamilton Beach Blender

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• Hamilton Beach Mixer
• Water bath
• No. 200 sieve
• Moisture Analyzer
• API Filter press
• Mud balance

3.2 The unweighted and weighted Mucuna solannie mud compositions are given in TABLE 3.2.

Table.3.2: Unweighted and Weighted mud Compositions

Mud Compositions	
Unweighted *Mucuna solannie* Mud Fresh Water 1 BBL Caustic soda 0.25 ppb *Mucuna solannie* 3 ppb Brachystegia e. 3 ppb *Pleurotus* 3 ppb XCD polymer 0.75 ppb	Weighted *Mucuna solannie* Mud Fresh Water 1 BBL Caustic soda 0.25 ppb *Mucuna solannie* 6 ppb Brachystegia e. 6 ppb *Pleurotus* 8 ppb *Potassium chloride* 20 ppb XCD Polymer 1 ppb *Barite* 75.4 ppb

3.3 Experimental Procedures

The unweighted and weighted muds were prepared based on 6 ppb concentration. The unweighted mud was formulated by mixing Fresh Water (1 BBL) with 0.25ppb Caustic soda, 3ppb *Mucuna solannie*, 3ppb Brachystegia e., 3ppb *Pleurotus* and 0.75ppb XCD polymer.

The weighted mud was prepared with 1 BBL Fresh Water, 0.25ppb Caustic soda, 6ppb *Mucuna solannie*, 6ppb Brachystegia e, 8ppb *Pleurotus*, 20ppb *Potassium Chloride*, 1ppb XCD Polymer and 75.4ppb *Barite*. The mud formulations were left for about 10 hours to age.

Hamilton Beach Mixer was used to mix the muds in a cup. The required temperature conditions of 120ºF and 180ºF were achieved by the use of a water bath, and the Fann six-speed Model 35A viscometer was used to take readings at 600 rpm, 300 rpm, 200 rpm, 100 rpm, 6 rpm and 3 rpm using the API guidelines. The 10sec and 10 minutes Gel Strengths were also measured with the viscometer. The Filter Press was used to measure the 30 minutes static fluid loss properties of the unweighted and weighted muds at the temperatures given, following the API procedures.

IV. RESULTS AND DISCUSSION

4.1 The viscometric readings are given in TABLE 4.1. Given also are the 10 seconds and 10 minutes get strengths, and the fluid losses.

Table4.1: Viscometric Readings and Fluid Loss for Unweighted and Weighted muds

Mud Composition	Ambient Temperature 95ºF	120ºF	180ºF
Unweighted *Mucuna solannie* Mud **Fresh Water 1 BBL** **Caustic soda 0.25 ppb** ***Mucuna solannie* 3 ppb** **Brachystegia e. 3 ppb** ***Pleurotus* 3 ppb** **XCD Polymer 0.75 ppb**	Fann Readings 44,37,33,27, 7,5 10s/10mins Gel=5/5 30mins F/L =17ml	Fann Readings 33,26,20,14, 3,3 10s/10mins Gel =3/3 30mins F/L =17ml	Fann Readings 29,23,17,13, 2,2 10s/10mins Gel = 3/2 30mins F/L =19.5ml
Weighted *Mucuna solannie* Mud **Fresh Water 1 BBL** **Caustic soda 0.25 ppb** ***Mucuna solannie* 6 ppb** **Brachystegia e. 6 ppb** ***Pleurotus* 8 ppb** ***Potassium chloride* 20 ppb** **XCD Polymer 1 ppb** ***Barite* 75.4 ppb**	Fann Readings 68, 56 ,50, 38, 6, 5 10s/10mins Gel=5/6 Fluid Loss=8.8ml	Fann Readings 72, 61, 53, 40 ,4, 3 10s/10mins Gel=4/5 Fluid Loss=10.4ml	Fann Readings 35, 26 , 20, 13 , 4, 3 10s/10mins Gel=2/2 Fluid Loss=13.5ml

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4.2 Effects of Temperature on Mud Properties

Fig. 4.1A, Fig. 4.2A, Fig. 4.3A, Fig. 4.4A and Fig. 4.5A show the effect of temperature on plastic viscosity, yield point, low shear rate yield point, fluid loss and apparent viscosity respectively for the unweighted mud and Fig. 4.6B, Fig. 4.7B, Fig. 4.8B, Fig. 4.9B and Fig. 4.10B for plastic viscosity, yield point, low shear rate yield point, fluid loss and apparent viscosity respectively for weighted mud.

For the unweighted mud, as the temperature increased from 95ºF to180ºF;

- the plastic viscosity **decreased**,
- the yield point **decreased**,
- low shear rate yield point **decreased**,
- fluid loss **increased** and
- apparent viscosity **decreased**

For the weighted muds, as the temperature increased from 95ºF to180ºF;

- the plastic viscosity, yield point, low shear rate yield point and apparent viscosity **decreased**, while
- the fluid loss **increased**

Generally, the fluid losses recorded in unweighted mud were higher than weighted mud.

4.2.1 Effect of Temperature on Mud Properties (Unweighted mud)

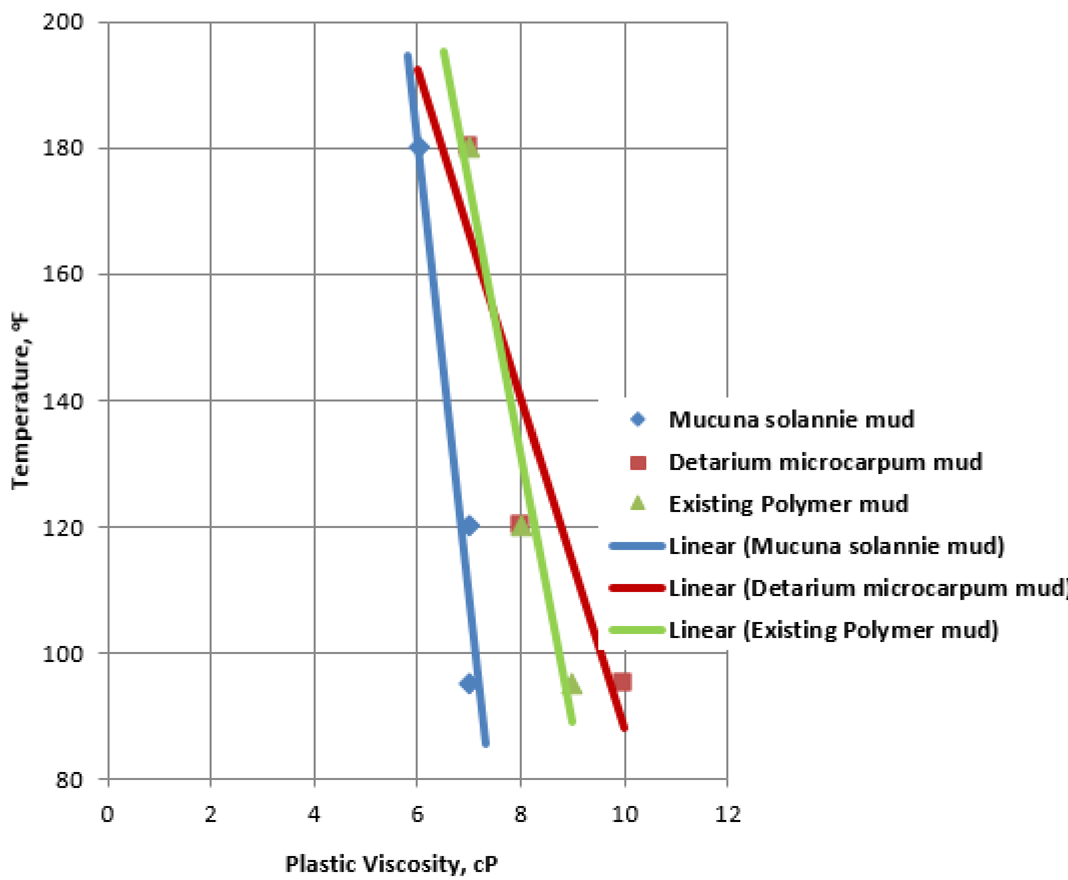

Fig. 4.1A: The Effect of Temperature on Plastic Viscosity for Unweighted mud

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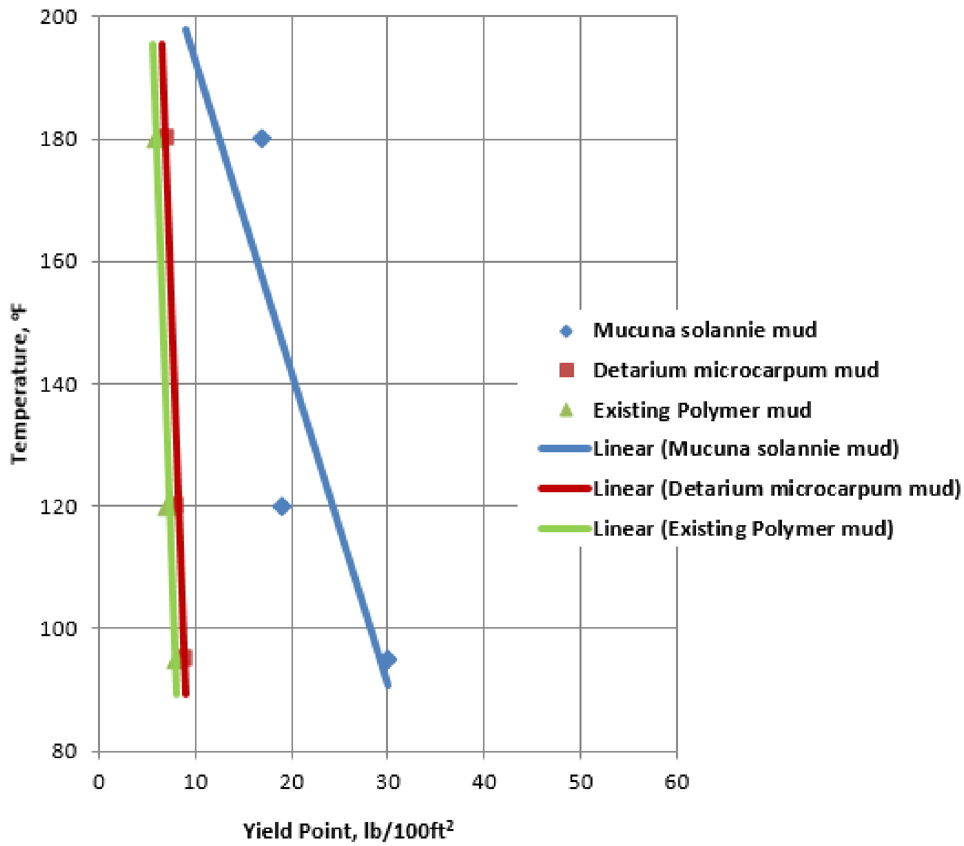

Fig. 4.2A: The Effect of Temperature on Yield Point for Unweighted mud

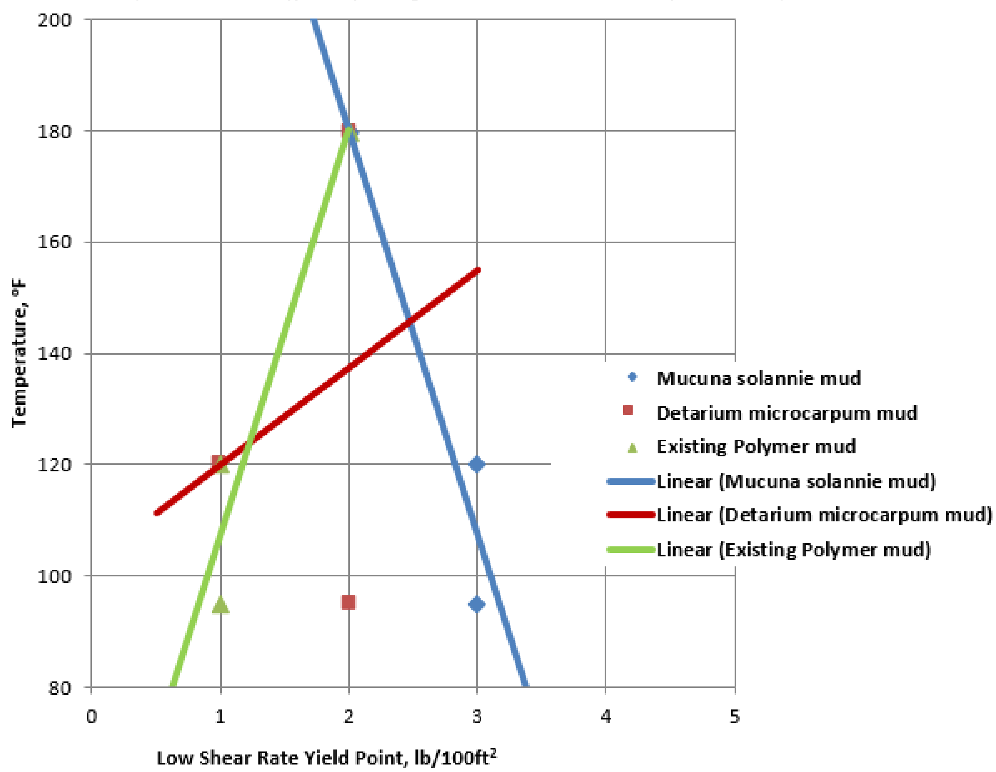

Fig. 4.3A: The Effect of Temperature on Low Shear Rate Yeild Point for Unweighted mud

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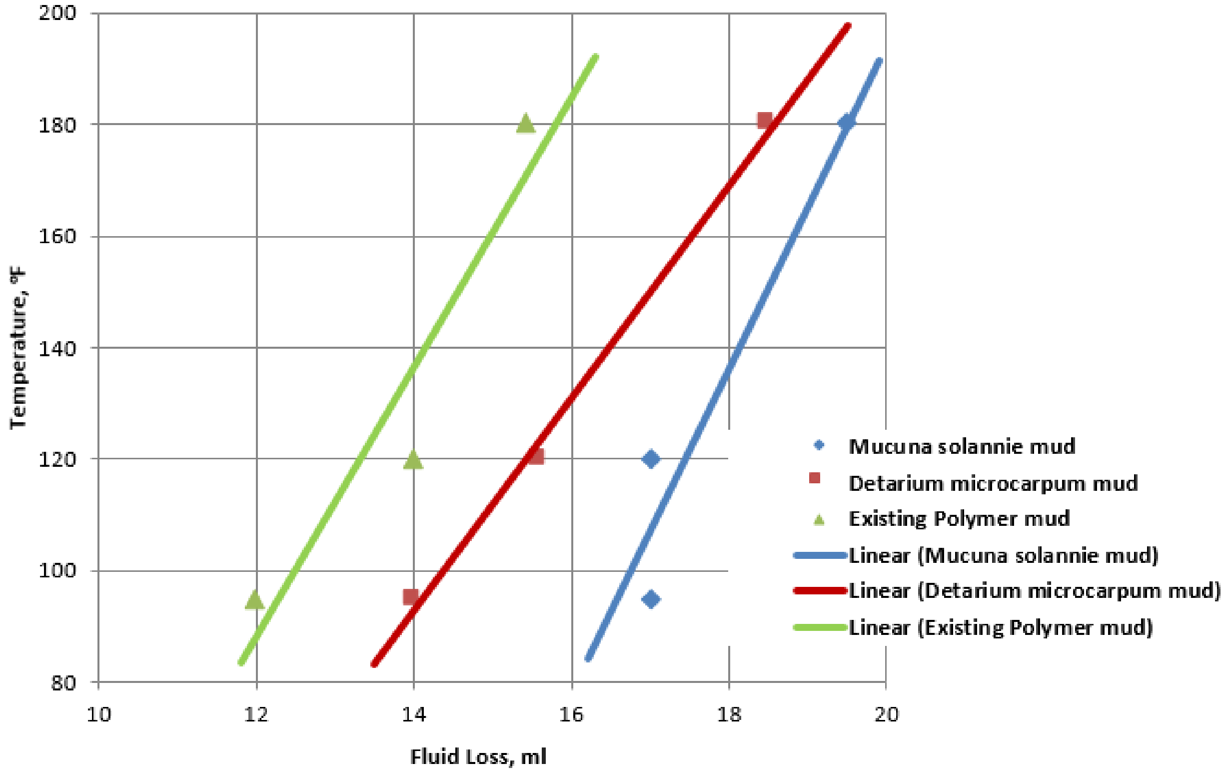

Fig. 4.4A: The Effect of Temperature on Fluid Loss for Unweighted mud

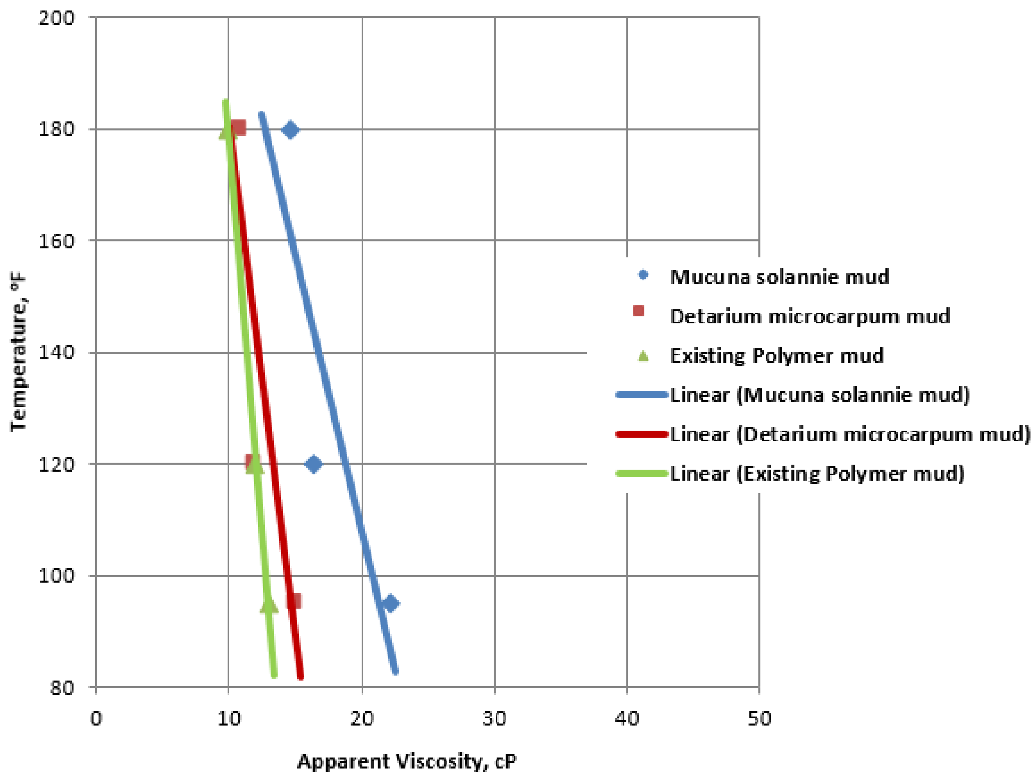

Fig. 4.5A: The Effect of Temperature on Apparent Viscosity for Unweighted mud

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4.2.2 Effect of Temperature on Mud Properties (Weighted mud)

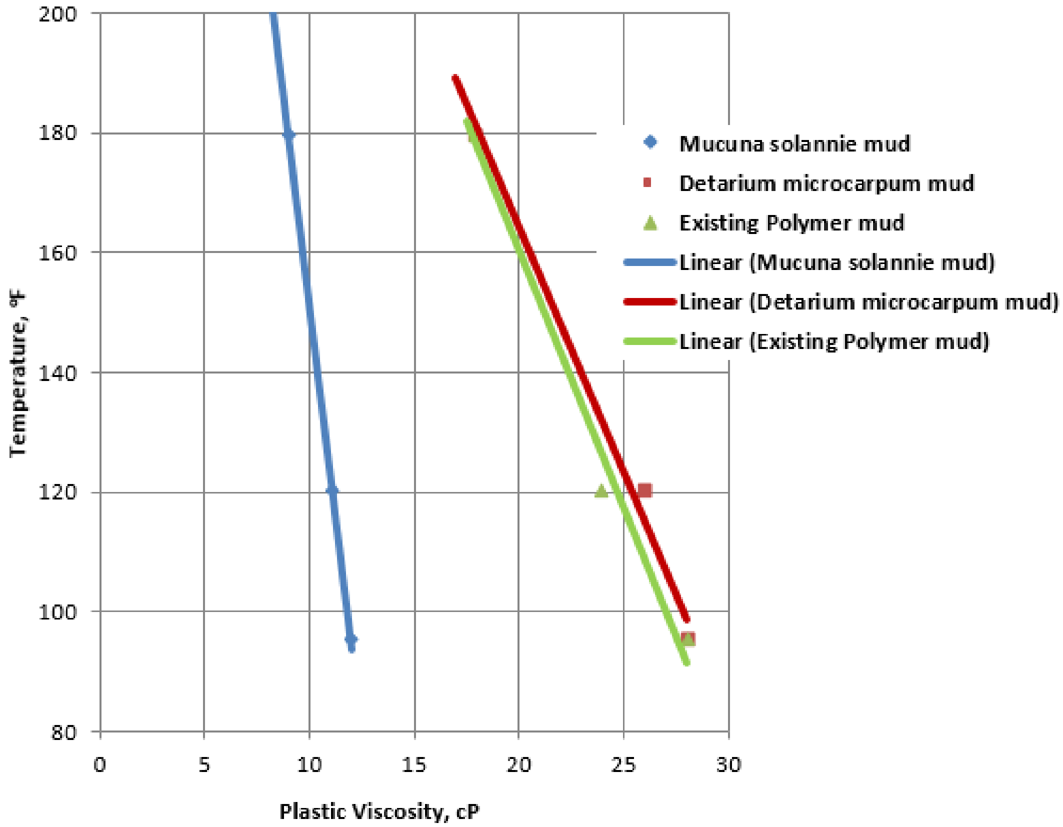

Fig. 4.6B: The Effect of Temperature on Plastic Viscosity for Weighted mud

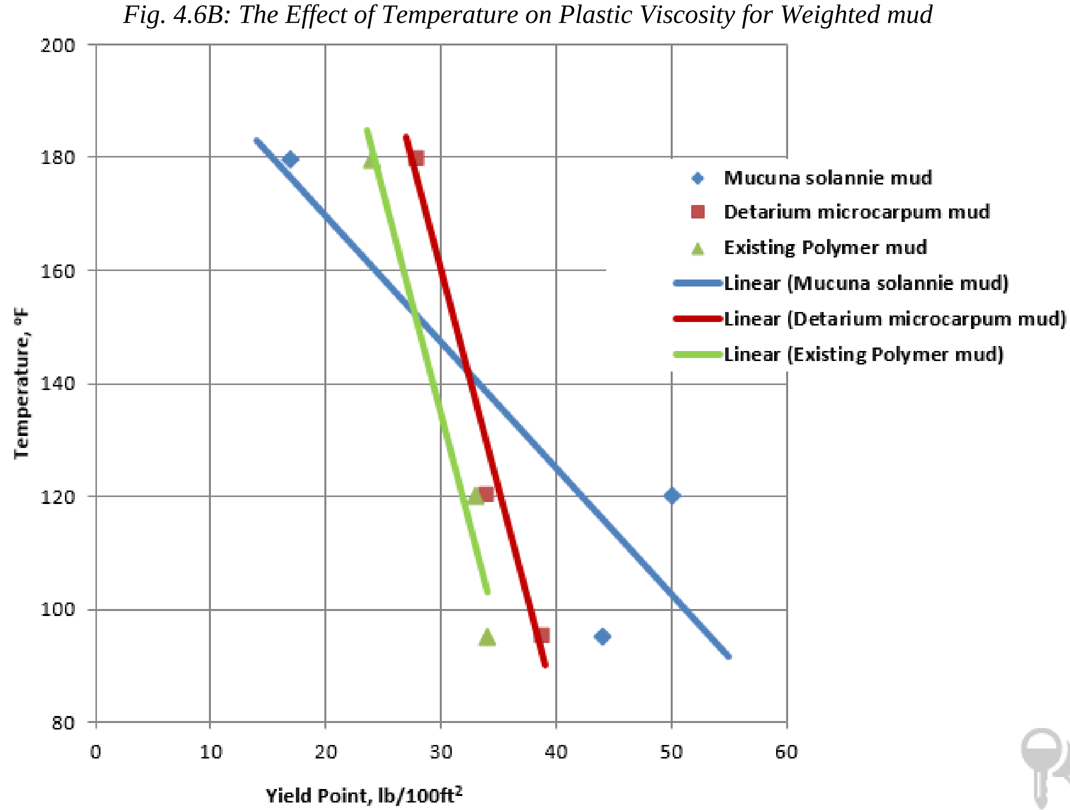

Fig. 4.7B: The Effect of Temperature on Yield Point for Weighted mud

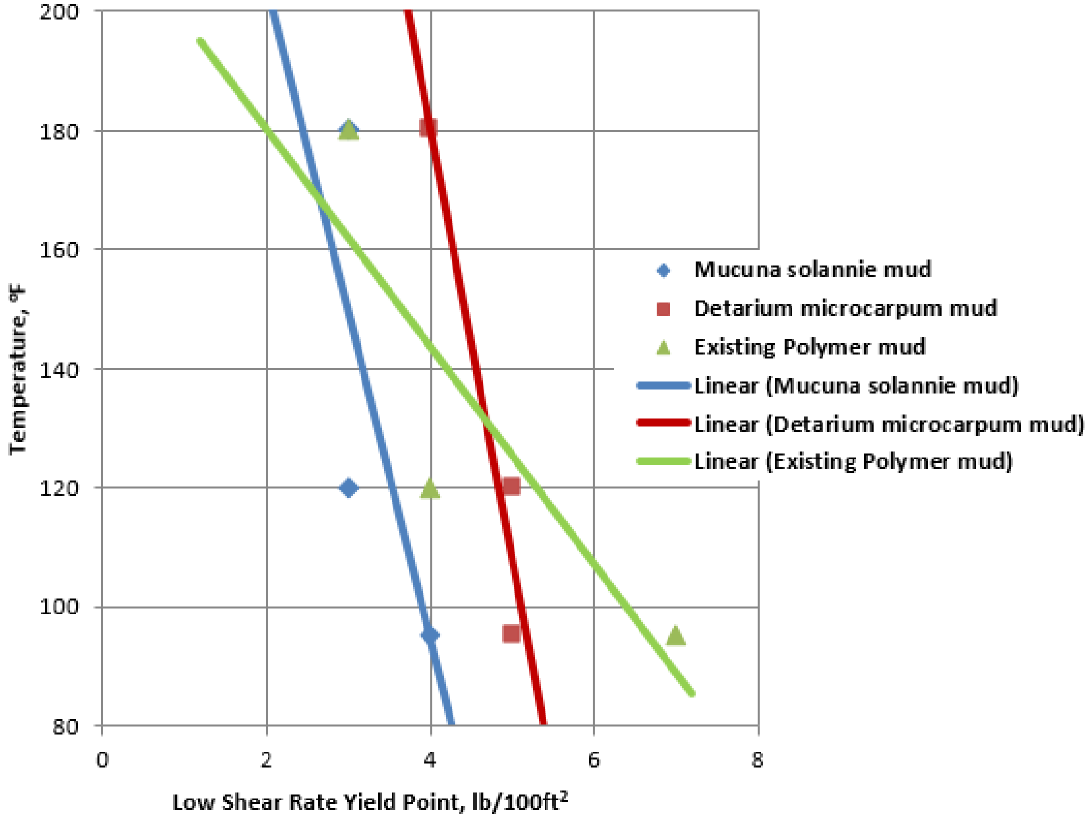

Fig. 4.8B: The Effect of Temperature on Low Shear Rate Yield Point for Weighted mud

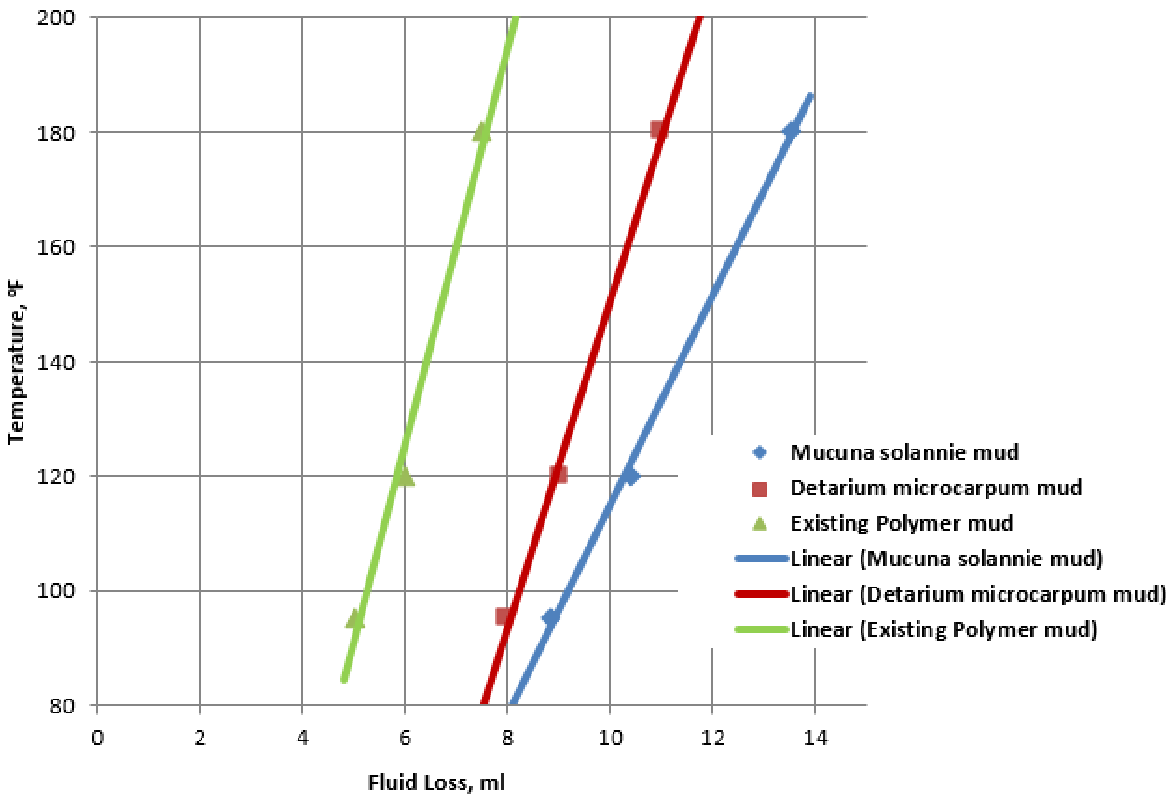

Fig. 4.9B: The Effect of Temperature on Fluid Loss for Weighted mud

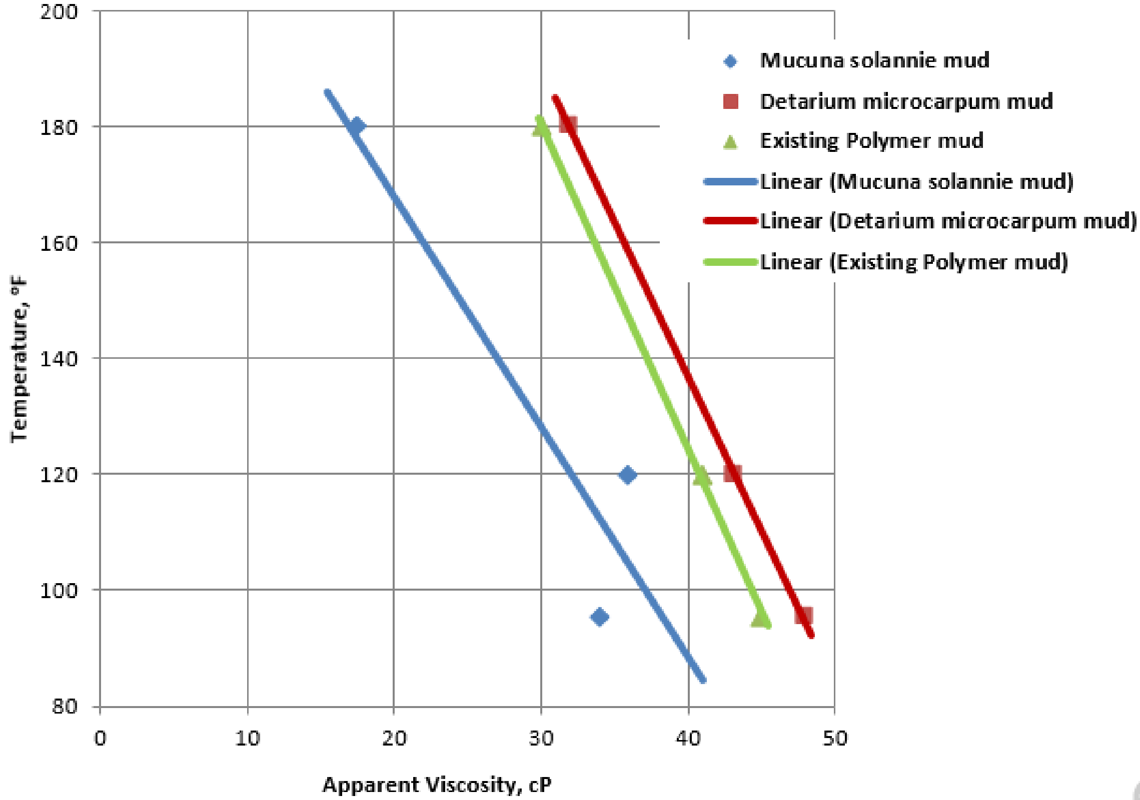

Fig. 4.10B: The Effect of Temperature on Apparent Viscosity for Weighted mud

4.2.3 Effect of Temperature on Density of Muds

Given in TABLE 4.2 are the densities of the unweighted and weighted muds measured.

Table.4.1: Effects of Temperature on Density of Unweighted and Weighted muds

	Density, ppg		
Mud Composition	**Ambient Temperature, 95ºF**	**120ºF**	**180ºF**
Unweighted *Mucuna solannie* Mud	6.4	6.4	6.4
Weighted *Mucuna solannie* Mud	8.6	8.6	8.6

V. CONCLUSIONS

1. It has been shown that temperature affects the water-based mud formulated out of *Mucuna solannie*, like it affects other muds.
2. Particularly, Plastic Viscosity, Yield Point, Low Shear Rate Yield Point and Apparent Viscosity decrease with temperature, while Fluid Loss increases with increase in temperature for both unweighted and weighted muds.
3. Temperature did not have an effect on the density of the muds.

NOMENCLATURE

ppb pounds per barrel
ppg pounds per gallon
XCD Xanthan Gum

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